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**Chen**

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(54) **PASSIVATION SCHEME**

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**Related U.S. Application Data**

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(51) **Int. Cl.**

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**H01L 23/498** (2006.01)

**H01L 23/532** (2006.01)

**H01L 21/768** (2006.01)

**H01L 21/3105** (2006.01)

(52) **U.S. Cl.**

CPC .... **H01L 23/49811** (2013.01); **H01L 21/76802** (2013.01); **H01L 21/76828** (2013.01); **H01L 21/76831** (2013.01); **H01L 23/53204** (2013.01); **H01L 23/53295** (2013.01); **H01L 21/31058** (2013.01); **H01L 2224/13** (2013.01)

(58) **Field of Classification Search**

CPC ..... H01L 2224/45147

USPC ..... 438/612, 613, 618, 620; 257/E21.507

See application file for complete search history.

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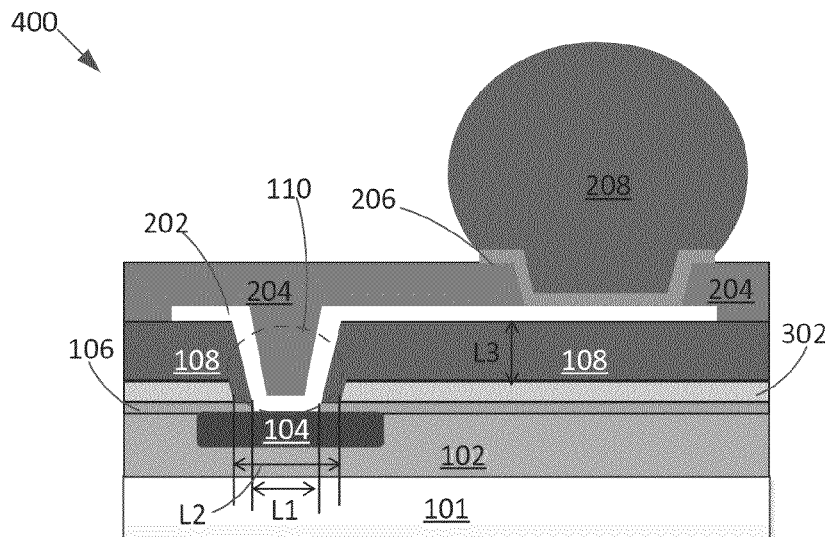
*Primary Examiner* — Julia Slutsker

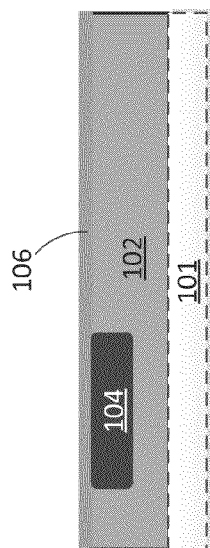
(74) *Attorney, Agent, or Firm* — Slater & Matsil, L.L.P.

(57) **ABSTRACT**

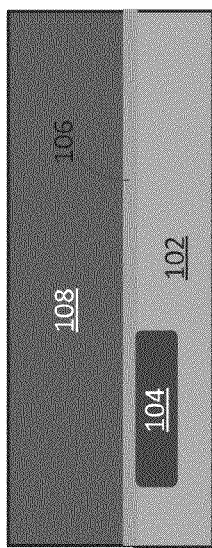
An integrated circuit includes a conductive pad disposed over a substrate. A first passivation layer is disposed over the conductive pad. A second passivation layer is disposed over the first passivation layer. A stress buffer layer is disposed over the second passivation layer. A conductive interconnect layer is over and coupled to the conductive pad and over the stress buffer layer with the conductive interconnect layer adjoining sidewalls of the first passivation layer and the stress buffer layer.

**20 Claims, 4 Drawing Sheets**

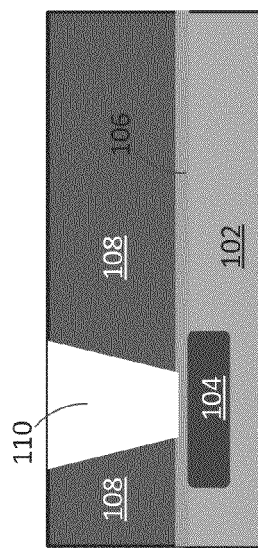




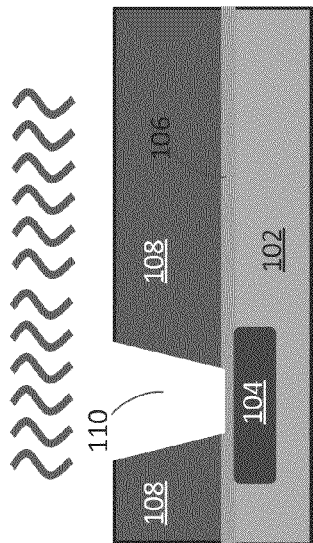
**Fig. 1A**



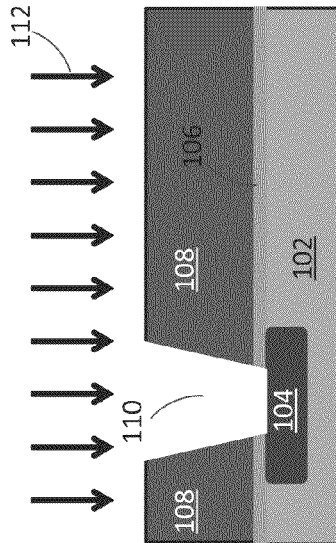
**Fig. 1B**



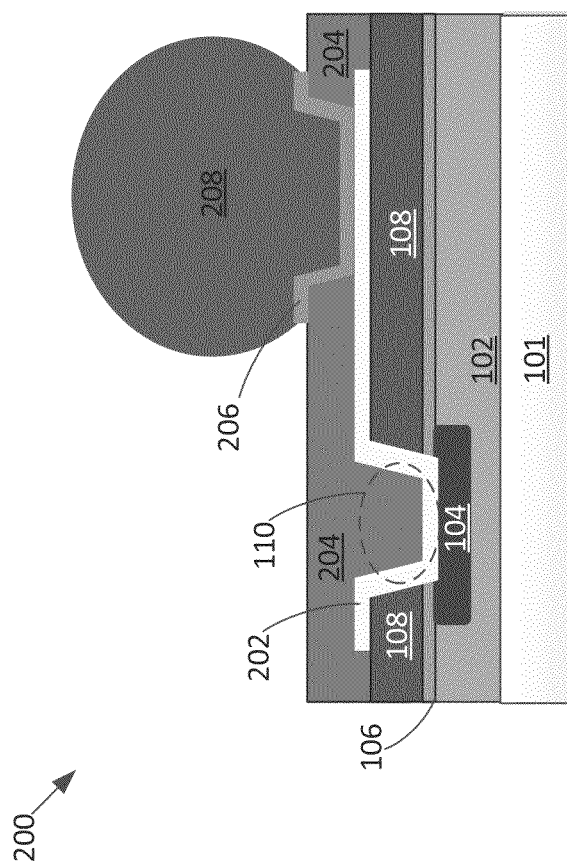
**Fig. 1C**



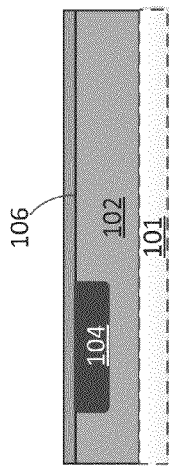
**Fig. 1D**



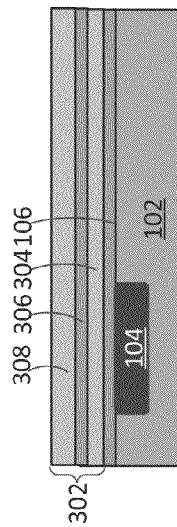
**Fig. 1E**



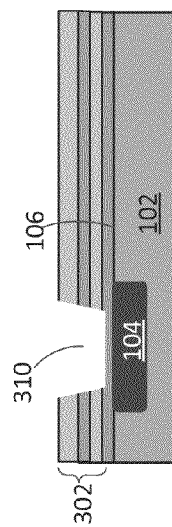
**Fig. 2**



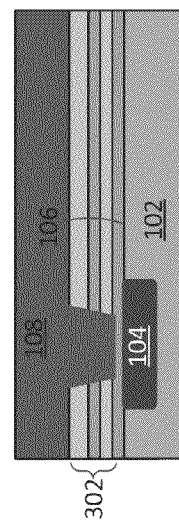
**Fig. 3A**



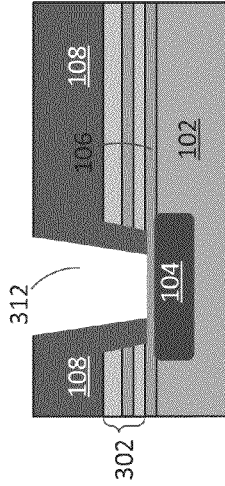
**Fig. 3B**



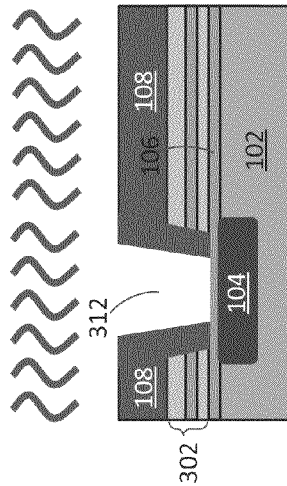
**Fig. 3C**



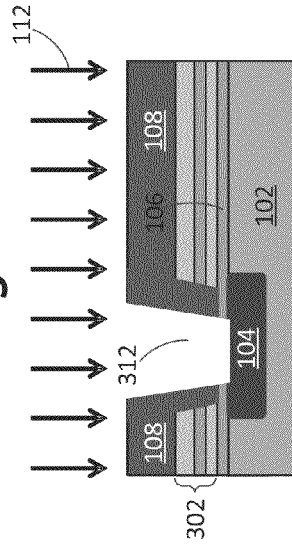
**Fig. 3D**



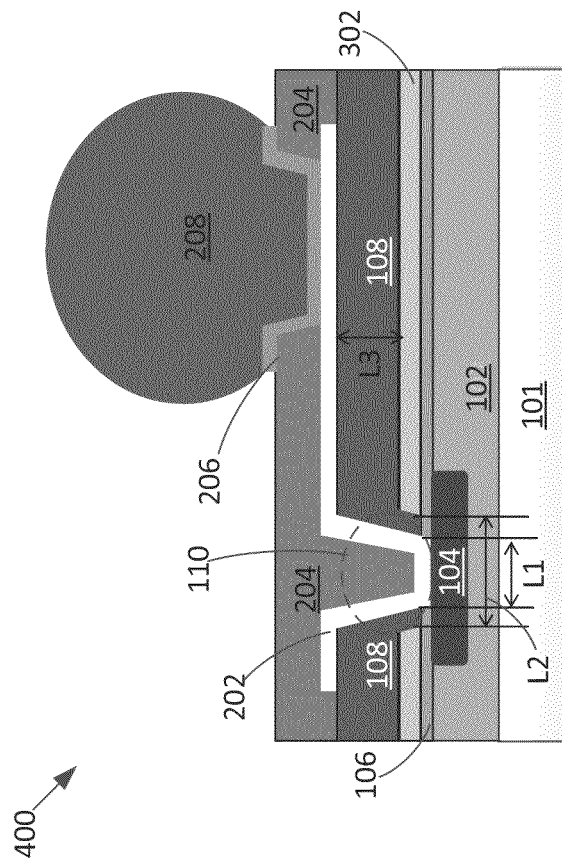
**Fig. 3E**



**Fig. 3F**



**Fig. 3G**



**Fig. 4**

# 1

## PASSIVATION SCHEME

### CROSS-REFERENCE TO RELATED APPLICATION

This application is a divisional application of U.S. patent application Ser. No. 13/629,180, filed on Sep. 27, 2012 and entitled "Passivation Scheme," which application is hereby incorporated herein by reference.

### TECHNICAL FIELD

The present disclosure relates generally to an integrated circuit and more particularly to a passivation scheme.

### BACKGROUND

For some passivation layer processes, curing a passivation layer such as polymer can cause oxidation of exposed Cu (copper) pads. The Cu pad oxidation may result in poor interconnection on the Cu pad and degrade device or circuit performance.

### BRIEF DESCRIPTION OF THE DRAWINGS

Reference is now made to the following descriptions taken in conjunction with the accompanying drawings, in which:

FIGS. 1A-1E are intermediate steps of an exemplary passivation scheme according to some embodiments;

FIG. 2 is a schematic diagram of an exemplary integrated circuit using the passivation scheme in FIGS. 1A-1E according to some embodiments;

FIGS. 3A-3G are intermediate steps of another exemplary passivation scheme according to some embodiments; and

FIG. 4 is a schematic diagram of another exemplary integrated circuit using the passivation scheme in FIGS. 3A-3G according to some embodiments.

### DETAILED DESCRIPTION

The making and using of various embodiments are discussed in detail below. It should be appreciated, however, that the present disclosure provides many applicable inventive concepts that can be embodied in a wide variety of specific contexts. The specific embodiments discussed are merely illustrative of specific ways to make and use, and do not limit the scope of the disclosure.

In addition, the present disclosure may repeat reference numerals and/or letters in the various examples. This repetition is for the purpose of simplicity and clarity and does not in itself dictate a relationship between the various embodiments and/or configurations discussed. Moreover, the formation of a feature on, connected to, and/or coupled to another feature in the present disclosure that follows may include embodiments in which the features are formed in direct contact, and may also include embodiments in which additional features may be formed interposing the features, such that the features may not be in direct contact. In addition, spatially relative terms, for example, "lower," "upper," "horizontal," "vertical," "above," "over," "below," "beneath," "up," "down," "top," "bottom," etc. as well as derivatives thereof (e.g., "horizontally," "downwardly," "upwardly," etc.) are used for ease of the present disclosure of one features relationship to another feature. The spatially relative terms are intended to cover different orientations of the device including the features.

FIGS. 1A-1E are intermediate steps of an exemplary passivation scheme according to some embodiments. In FIG. 1A,

2

a first passivation layer **106** ("liner") is formed over an electrically conductive pad **104** ("pad") and dielectric layer **102**. For example, the liner **106** can be deposited by chemical vapor deposition (CVD). The dielectric layer **102** is disposed over a substrate **101** (not shown in subsequent figures for simplicity). The dielectric layer **102** comprises SiO<sub>2</sub>, for example, and can be inter layer dielectric (ILD) or inter metallic dielectric (IMD) in some embodiments.

The substrate **101** can have electrical devices or components (e.g., transistors, resistors, capacitors, etc.) formed on the surface in some embodiments. The substrate **101** comprises silicon, silicon dioxide, silicon on insulator (SOI), aluminum oxide, sapphire, germanium, gallium arsenide (GaAs), an alloy of silicon and germanium, indium phosphide (InP), or any other suitable material. The pad **104** comprises copper or copper alloy in some embodiments.

The liner **106** is an etch stop layer and prevents moisture absorption. The liner **106** comprises SiN, SiON, SiO<sub>2</sub>, tetraethyl orthosilicate (TEOS), any combination thereof, or any other suitable material. The liner **106** has a thickness that ranges from 500 Å to 1500 Å in some embodiments. In one example, the liner **106** comprises SiN and has a thickness of about 750 Å. If the thickness of the liner **106** is too thick, it may be difficult to form an opening through the liner **106** later for interconnections. If the thickness of the liner **106** is too thin, the liner **106** may not be effective as an etch stop layer during some etching process and also it provides less stress buffer.

In FIG. 1B, a stress buffer layer **108** is formed (deposited) over the liner **106**. For example, the buffer layer **108** can be deposited by CVD. The stress buffer layer **108** provides a stress buffer and comprises polymer such as polyimide in some embodiments. The stress buffer layer **108** has a thickness that ranges from 5 μm to 20 μm in some embodiments. An exemplary stress buffer layer **108** in some applications has a glass transition temperature range from 200° C. to 380° C., an elongation range from 30% to 150%, and a coefficient of thermal expansion range from 30 ppm/K to 70 ppm/K. In other embodiments, the stress buffer layer **108** may have different properties.

In FIG. 1C, an opening **110** is formed through the stress buffer layer **108** over the electrically conductive pad **104** by photolithography. The opening **110** does not reach the electrically conductive pad **104**, stopped by the liner **106**.

In FIG. 1D, the stress buffer layer **108** is cured. A heat treatment is performed on the stress buffer layer **108** in some embodiments. For example, the curing process is conducted in an oven with inert gas (N<sub>2</sub>) or vacuum system with a curing time ranging from 60 min to 150 min and a curing temperature ranging from 150° C. to 350° C.

In FIG. 1E, the opening **110** is extended through the liner **106** to reach the pad **104** by self-aligned etching (after the curing in FIG. 1D). The liner **106** is etched (removed) while the buffer layer **108** functions as a mask and there is no additional photolithography process to define the etch location. The arrows **112** in FIG. 1E indicate an anisotropic plasma etch process, for example.

FIG. 2 is a schematic diagram of an exemplary integrated circuit **200** using the passivation scheme in FIGS. 1A-1E according to some embodiments. The integrated circuit **200** includes the substrate **101**, the dielectric layer **102**, and the pad **104** disposed over the substrate **101**.

The substrate **101** can comprise silicon, silicon dioxide, silicon on insulator (SOI), aluminum oxide, sapphire, germanium, gallium arsenide (GaAs), an alloy of silicon and germanium, indium phosphide (InP), or any other suitable material. The pad **104** comprises copper or copper alloy in some

embodiments. The dielectric layer **102** comprises  $\text{SiO}_2$ , for example, and can be inter layer dielectric (ILD) or inter metallic dielectric (IMD) in some embodiments.

The liner **106** disposed over the pad **104** is an etch stop layer and prevents moisture absorption. The liner **106** comprises SiN, SiON,  $\text{SiO}_2$ , tetraethyl orthosilicate (TEOS), any combination thereof, or any other suitable material. The liner **106** has a thickness that ranges from 500 Å to 1500 Å in some embodiment. In one example, the liner **106** comprises SiN and has a thickness of about 750 Å. If the thickness of the liner **106** is too thick, it may be difficult to form an opening through the liner **106** later for interconnections. If the thickness of the liner **106** is too thin, it may not be effective as an etch stop layer during some etching processes and it provides less stress buffer.

The stress buffer layer **108** is disposed over the liner **106** and functions as a stress buffer. The stress buffer layer **108** comprises polymer such as polyimide in some embodiments. The stress buffer layer **108** has a thickness that ranges from 5 μm to 20 μm in some embodiments. An exemplary stress buffer layer **108** in some applications has a glass transition temperature range from 200° C. to 380° C., an elongation range from 30% to 150%, and a coefficient of thermal expansion range from 30 ppm/K to 70 ppm/K. In other embodiments, the stress buffer layer **108** may have different properties.

The opening **110** through the liner **106** and the stress buffer layer **108** is made so that an interconnect layer **202** can be formed directly over the pad **104** through the opening **110** and over the stress buffer layer **108**. The stress buffer layer **108** does not have a physical contact with the pad **104** in the opening **110**. In comparison, for some other processes not using the self-aligned etch process in FIG. 1E, the stress buffer layer **108** may have a physical contact with the pad **104** in the opening **110** and there can be metal oxidation issue on the pad **104**.

Another stress buffer layer **204** is disposed over the interconnection layer **202** and the stress buffer layer **108**. The stress buffer layer **204** comprises polymer such as polyimide in some embodiments. The stress buffer layer **204** has a thickness that ranges from 5 μm to 20 μm in some embodiments. Under bump metal layer **206** is disposed over the interconnection layer **202** and the stress buffer layer **204** to provide electrical connection to a solder bump **208**. The solder bump **208** can be a micro-bump or a solder ball for a ball grid array (BGA), for example.

FIGS. 3A-3G are intermediate steps of another exemplary passivation scheme according to some embodiments. In FIG. 3A, a first passivation layer **106** ("liner") is formed over an electrically conductive pad **104** ("pad") and a dielectric layer **102**. For example, the liner **106** can be deposited by chemical vapor deposition (CVD). The dielectric layer **102** is disposed over a substrate **101** (not shown in subsequent figures for simplicity). The dielectric layer **102** comprises  $\text{SiO}_2$ , for example, and can be inter layer dielectric (ILD) or inter metallic dielectric (IMD) in some embodiments.

The substrate **101** can have electrical devices or components (e.g., transistors, resistors, capacitors, etc.) formed on the surface in some embodiments. The substrate **101** comprises silicon, silicon dioxide, silicon on insulator (SOI), aluminum oxide, sapphire, germanium, gallium arsenide (GaAs), an alloy of silicon and germanium, indium phosphide (InP), or any other suitable material. The pad **104** comprises copper or copper alloy in some embodiments.

The liner **106** is an etch stop layer and prevents moisture absorption. The liner **106** comprises SiN, SiON,  $\text{SiO}_2$ , tetraethyl orthosilicate (TEOS), any combination thereof, or any

other suitable material. The liner **106** has a thickness that ranges from 500 Å to 1500 Å in some embodiment. In one example, the liner **106** comprises SiN and has a thickness of about 750 Å. If the thickness of the liner **106** is too thick, it may be difficult to form an opening through the liner **106** later for interconnections. If the thickness of the liner **106** is too thin, it may not be effective as an etch stop layer during some etching processes and also there is less stress buffer.

In FIG. 3B, additional passivation layer **302** is formed (deposited) over the liner **106**. For example, the passivation layer **302** can be deposited by CVD. The additional passivation layer **302** may have one or more layers. The passivation layer **302** has a thickness ranging from 4 kilo-angstroms (KÅ) to 12 KÅ in some embodiments. In one example, the liner **106** comprises SiN with a thickness of 750 Å, the passivation layer **302** includes a buffer layer **304** comprising  $\text{SiO}_2$  with a thickness of 4 KÅ, another etch stop layer **306** comprising SiN with a thickness of 750 Å, and another buffer layer **308** comprising  $\text{SiO}_2$  with a thickness of 4 KÅ.

In FIG. 3C, an opening **310** is formed through the additional passivation layers **302** by photolithography, for example. The opening **110** does not reach the pad **104**, stopped by the liner **106**.

In FIG. 3D, a stress buffer layer **108** is formed (deposited) over the liner **106** and the additional passivation layer **302**. For example, the stress buffer layer **108** can be deposited by CVD. The stress buffer layer **108** provides a stress buffer and comprises polymer such as polyimide in some embodiments. The stress buffer layer **108** has a thickness that ranges from 5 μm to 20 μm in some embodiments. An exemplary stress buffer layer **108** has a glass transition temperature range from 200° C. to 380° C., an elongation range from 30% to 150%, and a coefficient of thermal expansion range from 30 ppm/K to 70 ppm/K in some applications. In other embodiments, the stress buffer layer **108** may have different properties.

In FIG. 3E, an opening **312** is formed through the buffer layer **108** over the electrically conductive pad **104** by photolithography, for example. The opening **312** does not reach the electrically conductive pad **104**, stopped by the liner **106**.

In FIG. 3F, the stress buffer layer **108** is cured. A heat treatment is performed on the stress buffer layer **108** in some embodiments. For example, the curing process is conducted in an oven with inert gas ( $\text{N}_2$ ) or vacuum system with a curing time ranging from 60 min to 150 min and a curing temperature ranging from 150° C. to 350° C.

In FIG. 3G, the opening **312** is extended through the liner **106** to reach the pad **104** by self-aligned etching (after the curing in FIG. 3F). The liner **106** is etched (removed) while the buffer layer **108** functions as a mask and there is no additional photolithography process to define the etch location. The arrows **112** in FIG. 1E indicate an anisotropic plasma etch process, for example.

FIG. 4 is a schematic diagram of another exemplary integrated circuit **400** using the passivation scheme in FIGS. 3A-3G according to some embodiments. The integrated circuit **400** is similar to the integrated circuit **200** except that there is an additional passivation layer **302** for additional buffer. The opening diameter L1 on the liner **106** is about 10 μm or larger, and the opening diameter L2 on the additional passivation layer **302** is 20 μm or larger in some embodiments.

The stress buffer layer **108** does not contact the electrically conductive pad **104** because of the liner **106**. In comparison, for some other processes not using the self-aligned etch process in FIG. 3G, the stress buffer layer **108** may have a physical contact with the pad **104** in the opening **110** and there can be metal oxidation issue on the pad **104**.

5

In some embodiments, the passivation layer **302** comprises SiO<sub>2</sub> and has a thickness that ranges from 4 KÅ to 12 KÅ. In some embodiments, the passivation layer **302** comprises multiple layers. In one example, the liner **106** comprises SiN with a thickness of 750 Å, the passivation layer **302** includes a buffer layer comprising SiO<sub>2</sub> with a thickness of 4 KÅ, another etch stop layer comprising SiN with a thickness of 750 Å, and another buffer layer comprising SiO<sub>2</sub> with a thickness of 4 KÅ.

According to some embodiments, an integrated circuit includes a conductive pad disposed over a substrate. A first passivation layer is disposed over the conductive pad. A second passivation layer is disposed over the first passivation layer. A stress buffer layer is disposed over the second passivation layer. A conductive interconnect layer is over and coupled to the conductive pad and over the stress buffer layer with the conductive interconnect layer adjoining sidewalls of the first passivation layer and the stress buffer layer.

According to some embodiments, a device includes a first passivation layer over a conductive pad. A second passivation layer is over the first passivation layer. A first stress buffer layer is over the second passivation layer with a bottom surface of the first stress buffer layer adjoining a top surface of the first passivation layer and a first sidewall of the first stress buffer layer adjoining a sidewall of the second passivation layer. A conductive interconnect is coupled to the conductive pad and extends over a top surface of the first stress buffer layer.

According to some embodiments, an integrated circuit includes a conductive pad over a substrate. A first passivation layer is over the conductive pad. A second passivation layer is over the first passivation layer. A first stress buffer layer is over the second passivation layer. A conductive interconnect is coupled to the conductive pad and extends through the first stress buffer layer and over the first stress buffer layer with the conductive interconnect adjoining sidewalls of the first passivation layer and the first stress buffer layer. A second stress buffer layer is over the conductive interconnect and the first stress buffer layer. A conductive bump is coupled to the conductive interconnect with the conductive bump extending through the second stress buffer layer.

A skilled person in the art will appreciate that there can be many embodiment variations of this disclosure. Although the embodiments and their features have been described in detail, it should be understood that various changes, substitutions and alterations can be made herein without departing from the spirit and scope of the embodiments. Moreover, the scope of the present application is not intended to be limited to the particular embodiments of the process, machine, manufacture, and composition of matter, means, methods and steps described in the specification. As one of ordinary skill in the art will readily appreciate from the disclosed embodiments, processes, machines, manufacture, compositions of matter, means, methods, or steps, presently existing or later to be developed, that perform substantially the same function or achieve substantially the same result as the corresponding embodiments described herein may be utilized according to the present disclosure.

The above method embodiment shows exemplary steps, but they are not necessarily required to be performed in the order shown. Steps may be added, replaced, changed order, and/or eliminated as appropriate, in accordance with the spirit and scope of embodiment of the disclosure. Embodiments that combine different claims and/or different embodiments are within the scope of the disclosure and will be apparent to those skilled in the art after reviewing this disclosure.

6

What is claimed is:

1. An integrated circuit comprising:
  - a conductive pad disposed over a substrate;
  - a first passivation layer disposed over the conductive pad;
  - a second passivation layer disposed over the first passivation layer;
  - a stress buffer layer disposed over the second passivation layer; and
  - a conductive interconnect layer over and coupled to the conductive pad and over the stress buffer layer, the conductive layer directly contacting sidewalls of the first passivation layer and the stress buffer layer, the stress buffer layer extending along a top surface and a sidewall of the second passivation layer and directly contacting the first passivation layer.
2. The integrated circuit of claim 1, wherein the conductive pad comprises copper or copper alloy.
3. The integrated circuit of claim 1, wherein the first passivation layer comprises SiN, SiON, SiO<sub>2</sub>, tetraethyl orthosilicate (TEOS), or any combination thereof.
4. The integrated circuit of claim 1, wherein the first passivation layer has a thickness that ranges from 500 Å to 1500 Å.
5. The integrated circuit of claim 1, wherein the stress buffer layer comprises a polymer.
6. The integrated circuit of claim 1, wherein the stress buffer layer is not in physical contact with the conductive pad.
7. The integrated circuit of claim 1, wherein the second passivation layer comprises multiple layers.
8. The integrated circuit of claim 1, wherein the second passivation layer is formed to have a thickness that ranges from about 4 kilo-Angstroms (KÅ) to about 12 KÅ.
9. A device comprising:
  - a first passivation layer over a conductive pad;
  - a second passivation layer over the first passivation layer;
  - a first stress buffer layer over the second passivation layer, a bottom surface of the first stress buffer layer directly contacting a top surface of the first passivation layer and a first sidewall of the first stress buffer layer directly contacting a sidewall of the second passivation layer; and
  - a conductive interconnect coupled to the conductive pad and extending over a top surface of the first stress buffer layer.
10. The device of claim 9, wherein the conductive interconnect directly adjoins a second sidewall of the first stress buffer layer and a sidewall of the first passivation layer.
11. The device of claim 9 further comprising:
  - a second stress buffer layer over the conductive interconnect and the first stress buffer layer;
  - an under bump metal layer coupled to the conductive interconnect and extending over the second stress buffer layer; and
  - a conductive bump coupled to the under bump metal layer.
12. The device of claim 9, wherein the second passivation layer further comprises:
  - a first buffer layer on the first passivation layer;
  - an etch stop layer on the first buffer layer; and
  - a second buffer layer on the etch stop layer.
13. The device of claim 9, wherein the first passivation layer comprises SiN, SiON, SiO<sub>2</sub>, tetraethyl orthosilicate (TEOS), or any combination thereof.
14. The device of claim 9, wherein the first stress buffer layer comprises a polymer.
15. An integrated circuit comprising:
  - a conductive pad over a substrate;
  - a first passivation layer over the conductive pad;



a second passivation layer over the first passivation layer;  
a first stress buffer layer over the second passivation layer;  
a conductive interconnect coupled to the conductive pad  
and extending through the first stress buffer layer and  
extending along a top surface of the first stress buffer 5  
layer, the conductive interconnect directly contacting  
sidewalls of the first passivation layer and the first stress  
buffer layer;  
a second stress buffer layer over top surfaces of the con-  
ductive interconnect and the first stress buffer layer, at 10  
least a portion of the second stress buffer layer extending  
below the top surface of the first stress buffer layer; and  
a conductive bump coupled to the conductive interconnect,  
the conductive bump extending through the second  
stress buffer layer. 15

16. The integrated circuit of claim 15, wherein the first  
stress buffer layer and the second stress buffer layer each  
comprise a polymer.

17. The integrated circuit of claim 15, wherein the first  
passivation layer comprises SiN, SiON, SiO<sub>2</sub>, tetraethyl 20  
orthosilicate (TEOS), or any combination thereof.

18. The integrated circuit of claim 15, wherein the first  
stress buffer layer is not in physical contact with the conduc-  
tive pad.

19. The integrated circuit of claim 15, wherein the first 25  
stress buffer layer is interposed between a sidewall of the  
conductive interconnect and a sidewall of the second passi-  
vation layer.

20. The integrated circuit of claim 1, wherein a bottom  
surface of the stress buffer layer contacts a top surface of the 30  
first passivation layer.

\* \* \* \* \*